ANNEX F

EARTHQUAKES

I. TYPE OF HAZARD

Earthquakes

II. DESCRIPTION OF HAZARD

Earthquakes are defined as shifts in the earth's crust causing the surface to become unstable. This instability can manifest itself in intensity from slight tremors to large shocks. The duration can be from a few seconds up to 5 minutes. The period of tremors (and shocks) can last up to several months. The larger shocks can cause ground failure, landslides, liquefaction, uplifts, and sand blows.

The earth's crust is made up of gigantic plates, commonly referred to as tectonic plates. These plates form what is know as the lithosphere, which varies in thickness from 6.5 miles (beneath oceans) to 40 miles (beneath mountain ranges), and has an average thickness of 20 miles. These plates "float" over a partly melted layer of crust called the asthenosphere. The plates are in motion, and areas where one plate joins another are referred to as “plate boundaries.” Areas where the plates are moving toward each other are called convergent plate boundaries, and areas when they are moving away from each other are called divergent plate boundaries. The San Andreas Fault in California is a horizontal motion boundary, where the Pacific plate is moving to the north while the North American plate is moving to the west. These movements release built-up energy in the form of earthquakes, tremors, and volcanic activity. Fault lines such as the San Andreas come all the way to the surface and can be readily seen and identified. Some fault lines do not come all the way to the surface, yet they can store and release energy when they move. Many of the faults in the central United States are characterized this way.

The subterranean faults were formed many millions of years ago on or near the surface of the earth. Subsequent to that time, these ancient faults subsided, while the adjacent areas were pushed up. As this fault zone (also known as a rift) lowered, sediments filled in the lower areas. Under pressure, sediments hardened into limestones, sandstones, and shales, thus burying the rifts. With the pressure on the North Atlantic ridge affecting the eastern side of the North American plate, and the movements along the San Andreas Fault by the Pacific plate, the buried rift system, in the Mississippi embayment has been reactivated. This particular rift system is now called the Reelfoot Rift.

Eight earthquake source zones are located in the central United States, two of which are located within the State of Missouri. The most active zone is the New Madrid Fault, which runs from northern Arkansas through southeast Missouri and western Tennessee and Kentucky to the Illinois side of the Ohio River Valley. Other zones, because of their close proximity, also affect Missourians. These are the Wabash Valley Fault, Illinois Basin, and the Nemaha Uplift.

The Nemaha Uplift is of concern to Missourians because it runs parallel to the Missouri/Kansas border from Lincoln, Nebraska, to Oklahoma City, Oklahoma. Earthquakes from the Nemaha Uplift are not as severe as those associated with the historic New Madrid fault zone, several earthquakes have affected Missouri in the past.

III. HISTORICAL STATISTICS

The most severe earthquakes occurred in the New Madrid fault zone during a period between December 16, 1811, and March 12, 1812. An engineer in Louisville, Kentucky, counted over 1,850 shocks during this time, including three earthquakes of magnitude greater than 8.3 (Richter magnitude). The shocks from these earthquakes could be easily felt as far away as Detroit, Michigan, and Charleston, South Carolina. The area between the St. Francois River and Mississippi River south of New Madrid to Marked Tree, Arkansas, showed numerous sand blows. A sand blow is a place where liquefacted alluvial soil has geysered out of the surface. Liquefaction is a phenomenon where the shaking of the ground separates the water from the soil holding it, causing the soil to behave like a dense liquid. The lack of water causes the soil to lose surface cohesion, and sand from these blows accumulates to a depth of up to 5 feet in places. Liquefaction causes land to lose its load-bearing capacity.

Areas uplifted as well as subsided (dropped) along the Mississippi River. For instance, the area around Tiptonville, Tennessee, formed a dome (uplift of several yards). Immediately adjacent to the Tiptonville Dome, an area subsided to form a lake 18 miles long and 5 miles wide. It is now known as Reelfoot Lake and is a tourist and recreation area. Ground failure and landslides were apparent throughout the bluffs (Chickasaw Bluffs) alongside the Mississippi River in Kentucky and Tennessee. Many fissures were made throughout the region, and one local observer recorded that the earth seemed to be rolling in waves a few feet in height. These swells would burst, leaving wide and long fissures. The damage to the area was so severe that Congress passed, and President James Madison signed into law, the first disaster relief act, giving government lands in other territories to people wanting to move out of the area.

During the past decade, an earthquake of 3.1 Richter magnitude occurred on March 31, 1993, close to the Cooper Nuclear Power Station in Brownville, Nebraska. No damages resulted, but the earthquake was felt across the Missouri River near Rock Port, Missouri.

IV. MEASURE OF PROBABILITY AND SEVERITY

The Center for Earthquake Research and Information at the University of Memphis has computed conditional probabilities of a magnitude 6.0 Richter earthquake in the New Madrid fault zone. According to a fact sheet prepared by State Emergency Management Agency (SEMA) in 2003, the probability for a magnitude 6.0 to 7.5 or greater earthquake along the New Madrid Fault is 25 to 40 percent over the next 50 years. With approximately 12.5 million people living in the area, steps are being taken to reduce related hazards to citizens and property in the area. The probability of an earthquake increases with each day, which makes it difficult to rate. Based on the information from the Center for Earthquake Research and Information (University of Memphis), the probability of an earthquake is rated as moderate, and the severity is rated as high.

V. IMPACT OF THE HAZARD

The impacts of earthquakes on Missouri can be significant. The three New Madrid earthquakes of 1811-1812 may be the largest that have happened on the North American continent. Although losses were limited because of the sparse population of the time, many Native Americans died and property was damaged to the point that resettlement became a national policy.

Several studies indicate the need to prepare for earthquakes, as scholars estimate that the New Madrid Fault has the capability of generating Mercalli intensities of X (ten) in Southeast Missouri. The late Dr. Otto Nuttli of St. Louis University stated in his book, “The Effects of Earthquakes in the Central United States,” that surface-wave magnitudes of 7.6 (Richter) would create the largest possible

earthquake that could occur anywhere along the New Madrid fault in the near future. Information on preparedness and predictions related to the New Madrid Fault is provided on the U. S. Geological Survey Earthquake Hazards Program website: www.usgs.gov/hazards, and the Center for Earthquake Research and Information website: www.ceri.memphis.edu/usgs.

VI. SYNOPSIS

The chances of an earthquake increase each day. Energy from the movement of the North American tectonic plate continues to build up along both the New Madrid and Nemaha Faults and their subsidiary fault systems. The state will have an earthquake. We don't know exactly where or when, but we are overdue for a moderate earthquake. The earthquakes may affect the citizens of Missouri and surrounding states. Earthquakes also have secondary effects such as fires, building collapses, utility disruptions, flooding, hazardous materials releases, environmental impacts, and economic disruptions or losses.

VII. MAPS OR OTHER ATTACHMENTS

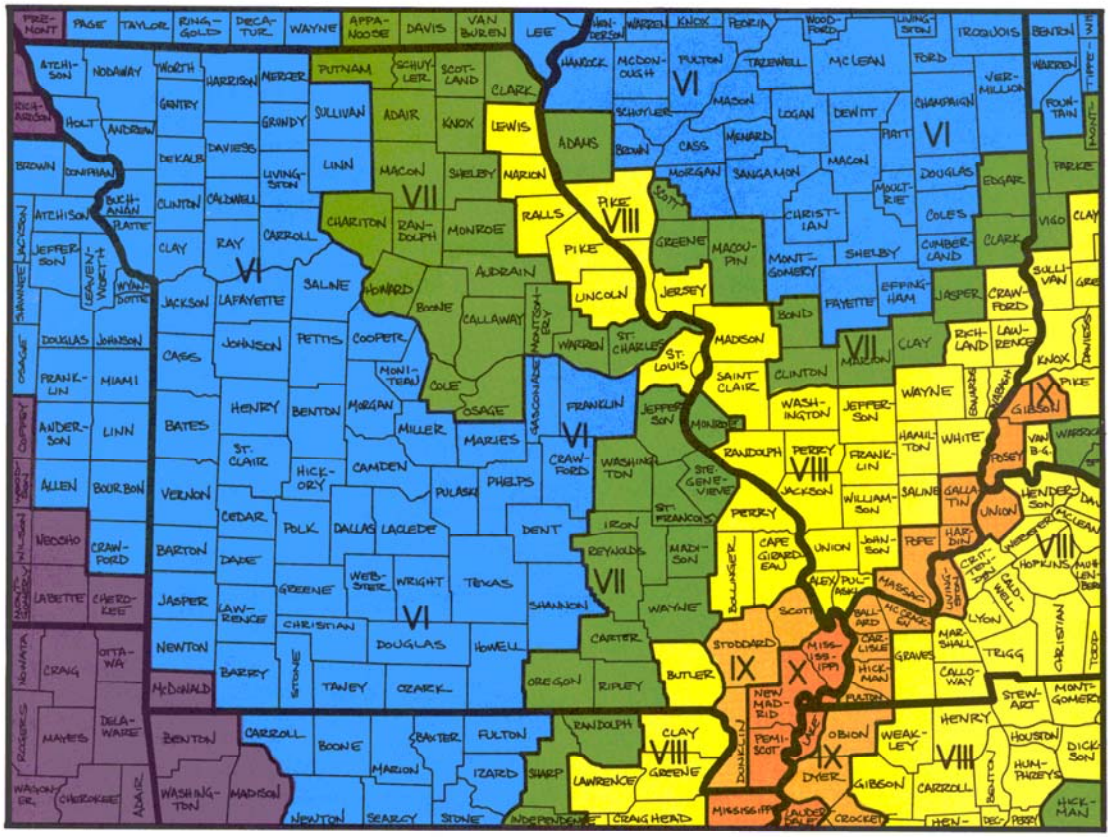
The attached figure shows the projected Modified Mercalli earthquake intensities by county expected from a 7.6 Richter magnitude earthquake along the New Madrid Fault. The secondary maps show the same relative intensities for these statewide regions for a 6.7 and an 8.6 Richter magnitude earthquake, respectively. The Modified Mercalli Intensity Scale descriptions are included following the maps in the figure. The intensity is a numerical index scale to describe the effects of an earthquake on the surface of the Earth, on man, and on man-made structures. Further discussion on this is included following the scale legend.

- Projected Earthquake Intensities: Figure F-1
- Moderate/Large Earthquakes in the Central United States.

FIGURE F-1

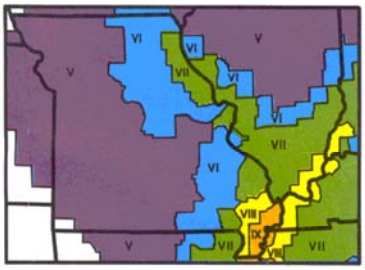
PROJECTED EARTHQUAKE INTENSITIES

This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone. The secondary maps show the same regional intensities for a 6.7 and an 8.6 earthquake, respectively. For a description of Projected Earthquake Intensities V through X, see the page following the maps.



This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude – 7.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

6.7



This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude – 6.7 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

7.6

This map shows the highest projected Modified Mercalli intensities by county from a potential magnitude – 8.6 earthquake whose epicenter could be anywhere along the length of the New Madrid seismic zone.

8.6

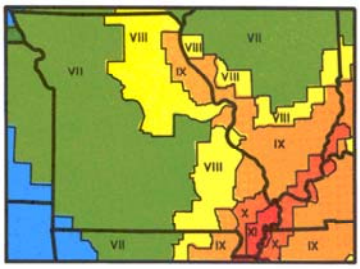


FIGURE F-1 (Continued)

PROJECTED EARTHQUAKE INTENSITIES

MODIFIED MERCALLI INTENSITY SCALE

I People do not feel any Earth movement.

II A few people might notice movement.

III Many people indoors feel movement. Hanging objects swing.

IV Most people indoors feel movement. Dishes, windows, and doors rattle. Walls and frames of structures creak. Liquids in open vessels are slightly disturbed. Parked cars rock.

V Almost everyone feels movement. Most people are awakened. Doors swing open or closed. Dishes are broken. Pictures on the wall move. Windows crack in some cases. Small objects move or are turned over. Liquids might spill out of open containers.

VI Everyone feels movement. Poorly built buildings are damaged slightly. Considerable quantities of dishes and glassware, and some windows are broken. People have trouble walking. Pictures fall off walls. Objects fall from shelves. Plaster in walls might crack. Some furniture is overturned. Small bells in churches, chapels and schools ring.

VII People have difficulty standing. Considerable damage in poorly built or badly designed buildings, adobe houses, old walls, spires and others. Damage is slight to moderate in well-built buildings. Numerous windows are broken. Weak chimneys break at roof lines. Cornices from towers and high buildings fall. Loose bricks fall from buildings. Heavy furniture is overturned and damaged. Some sand and gravel stream banks cave in.

VIII Drivers have trouble steering. Poorly built structures suffer severe damage. Ordinary substantial buildings partially collapse. Damage slight in structures especially built to withstand earthquakes. Tree branches break. Houses not bolted down might shift on their foundations. Tall structures such as towers and chimneys might twist and fall. Temporary or permanent changes in springs and wells. Sand and mud is ejected in small amounts.

IX Most buildings suffer damage. Houses that are not bolted down move off their foundations. Some underground pipes are broken. The ground cracks conspicuously. Reservoirs suffer severe damage.

X Well-built wooden structures are severely damaged and some destroyed. Most masonry and frame structures are destroyed, including their foundations. Some bridges are destroyed. Dams are seriously damaged. Large landslides occur. Water is thrown on the banks of canals, rivers, and lakes. Railroad tracks are bent slightly. Cracks are opened in cement pavements and asphalt road surfaces.

XI Few if any masonry structures remain standing. Large, well-built bridges are destroyed. Wood frame structures are severely damaged, especially near epicenters. Buried pipelines are rendered completely useless. Railroad tracks are badly bent. Water mixed with sand, and mud is ejected in large amounts.

XII Damage is total, and nearly all works of construction are damaged greatly or destroyed. Objects are thrown into the air. The ground moves in waves or ripples. Large amounts of rock may move. Lakes are dammed, waterfalls formed and rivers are deflected.

Intensity is a numerical index describing the effects of an earthquake on the surface of the Earth, on man, and on structures built by man. The intensities shown in these maps are the highest likely under the most adverse geologic conditions. There will actually be a range in intensities within any small area such as a town or county, with the highest intensity generally occurring at only a few sites. Earthquakes of all three magnitudes represented in these maps occurred during the 1811 - 1812 "New Madrid earthquakes." The isoseismal patterns shown here, however, were simulated based on actual patterns of somewhat smaller but damaging earthquakes that occurred in the New Madrid seismic zone in 1843 and 1895.

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P.O. BOX 116
JEFFERSON CITY, MO 65102
Telephone: 573-526-9100

FIGURE 1

MODERATE/LARGE EARTHQUAKES IN THE CENTRAL UNITED STATES

DATE	LOCALITY	AREA MILES	INTENSITY	SOURCE ZONE
Dec. 16, 1811	New Madrid, Missouri	2,000,000	XII	New Madrid Fault
Jan. 23, 1812	New Madrid, Missouri	2,000,000	XII	New Madrid Fault
Feb. 7, 1812	New Madrid, Missouri	2,000,000	XII	New Madrid Fault
June 9, 1838	Southern Illinois	Widespread	VI	Illinois Basin
Jan. 4, 1843	Western Tennessee	40,000	VIII	New Madrid Fault
Unknown, 1860	Central Minnesota	Unknown	Unknown	Colorado Lineament
Aug. 17, 1865	Southeastern Missouri	24,000	VII	New Madrid Fault
April 24, 1867	Lawrence, Kansas	300,000	VII	Nemaha Uplift
June 18, 1875	Western Ohio	40,000	VII	Cincinnati Arch
Nov. 15, 1877	Eastern Nebraska	140,000	VII	Nemaha Uplift
Oct. 22, 1882	Arkansas - Texas	135,000	VI - VII	Ouchita - Wichita Fault
July 26, 1891	Illinois - Indiana	Unknown	VI	Wabash Valley Fault
Oct. 31, 1895	Charleston, Missouri	1,000,000	VIII	New Madrid Fault
May 26, 1909	Illinois	500,000	VII	Cincinnati Arch
April 9, 1917	Eastern Missouri	200,000	VI	St. Francois Uplift
March 8, 1937	Western Ohio	150,000	VII - VIII	Cincinnati Arch
April 9, 1952	Enid, Oklahoma	140,000	VII	Nemaha Uplift
Nov. 9, 1968	South Central Illinois	580,000	VII	Wabash Valley Fault
March 24, 1976	Marked Tree, Arkansas	115,000	V - VI	New Madrid Fault
July 27, 1980	North Central Kentucky	375,000	VII	Cincinnati Arch
Jan. 31, 1986	Anna, Ohio	440,000	VI	Cincinnati Arch
June 9, 1987	Lawrenceville, Illinois	125,000	V - VI	Wabash Valley Fault
Sept. 26, 1990	Chaffee, Missouri	140,000	IV - V	New Madrid Fault
May 3, 1991	Risco, Missouri	150,000	IV - V	New Madrid Fault
Dec. 7, 2001	Evansville, Indiana	24,000	IV - V	Wabash Valley Fault
May 4, 2001	Conway, Arkansas	36,000 est.	III - IV	Ouchita - Wichita Fault

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